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Original Article

Investigation of Increasing Essential Oil and Maintaining Forage Quality and Digestibility of the *Prangos ferulacea* using an Optimizer Apparatus Design

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Abstract

The purpose of the present research was to evaluate the essential oil and forage quality optimizer (EFO) apparatus to improve oils, while preserving forage quality and digestibility for the first time. *Prangos ferulacea* L. Lindl aerial parts were collected and used for the essential oil, forage quality, and digestibility analysis. Effects of temperature treatments (60, 75 and 90 °C) at EFO method on essential oil were compared to steam distillation. After the oil extraction, the nutrient compositions were measured and compared with the samples of before extracting. The results showed a significant increase in the content of essential oil in 75 °C compared to the other treatments ($p<0.05$). Also, the quality and the digestibility of fodder were as follows: SD method < before the essential oil extraction < the EFO innovative method (75 °C). Therefore, temperature of 75 °C in EFO was concluded as the optimum temperature, for increasing both of the quality and quantity of oil as well as preserving the quality and digestibility of forage. It is suggested that the EFO can be tested to obtain a more qualitative essential oil and forage that can be exploited in the pharmaceutical and animal food industry.

Keywords: Essential oil and Forage quality Optimizer (EFO), SD (Steam distillation), *Prangos ferulacea*; Forage quality, Digestibility

Introduction

The medicinal and forage species grow up in most rangelands of the world and their various products including volatile oils and nutrients for livestock, can be exploited in medicine, feeding animal, and cosmetics industries [1,2]. Medicinal plants (MPs) are the richest bioresource of drugs for traditional systems of medicine, modern medicines, nutraceuticals, food supplements, folk medicines, pharmaceutical intermediates, and chemical entities for synthetic drugs. The first step in the value addition of MPs bioresources is producing herbal drug preparations (i.e. extracts and essential oils), using a variety of methods ranged from simple traditional technologies to the advanced extraction techniques. The problem occurring in the usual plant extraction methods is losses of volatile compounds after the distillation stage [3]. Moreover, the extraction and separation processes of plant volatile components are accomplished by various extraction methods. One of the approaches for quantitative and qualitative evaluations of essential oils is the comparison of essential oil extraction methods in terms of their amounts and composition of volatiles as well as the selection of the most appropriate method. Sahrawi and Bootkjirt [4] investigated yield and composition of *Thymus pallescens* Noë essential oil using a combination of microwave and steam distillation and reported that the extraction rate in this method is four times more than the rate of the extraction in the conventional steam distillation method. In another study, the effects of different pressure treatments on the essential oil yield of rosemary plants were investigated using a combination of vacuum pump and steam distillation. Also, the result showed that the 410 kPa

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pressure is the most suitable treatment based on the amount and oil composition.

Nowadays, if these plants, in addition to their medicinal properties, have forage value, the decreased forage quality after the extraction of essential oil can be another problem. Although previous studies have reported the medicinal qualities of particular plants [5]. The quality and quantity of chemical compounds and preserves the forage quality in medicinal-forage plants wasn't investigated. Traditionally, the valuable essential oil of the plant that is used as fodder, is removed from its aerial parts. Therefore, evaluating a method to increase the essential oil yield and quality and maintain the forage quality and digestibility of plant species, would be cost-effective economically.

One of the important forage plants with high quality [6-8] and valuable essential oils in aerial organs [9,10] is *P. ferulacea* L. Lindl. Performing phytochemical studies of plant aerial parts have led to the isolation of coumarins, alkaloids, flavonoids, and terpenoids [11-14]. Accordingly, these oils' composition has a great economic value due to its uses in the perfume, food, and pharmaceutical industries [15]. Before seeding stage, no livestock grazing was done for this forage plant. Due to the presence of abundant essential oils in the aerial parts, it used as dry fodder in winter for livestock most of the time [16]. The plant grows in the Zagros Mountains (west of Iran) and the aerial parts are collected in mid-spring (Fig. 1).

The purposes of this research were as follows: (i) introducing the apparatus of Essential oil and forage quality optimizer (EFO) with the aim of increasing the essential oil yield and preservation of the forage quality at medicinal-forage species for the first time, and (ii) examining this method with multipurpose species of *P. ferulacea* . that has a high nutritional and valuable essential oil, compared to the steam distillation (SD) method.

Material and Methods

Plant Material

P. ferulacea (L.) Lindl (Umbelliferae) is a forage and medicinal plant that grows in rangelands of central Asia and in 13 provinces of Iran [17]. The aerial parts of *P. ferulacea* were collected at the flowering stage, in May 2018 from natural populations in the Bistoon mountain of Kermanshah province in Iran (north-eastern slope at 34°27′ N and 46°55′ E). The specimens were identified in the Razi University Herbarium (RUH) by the botanist Dr. S.M. Masoumi. A voucher specimen was deposited under accession number 1184. While the first batch was subjected to SD and EFO methods and used for the essential oil, forage quality, and digestibility analysis; the second part used only in forage quality and digestibility analysis and compared them with the first batch.

Fig. 1 *P. ferulacea* L. Lindl grown in the northwest of Kermanshah, Iran

Analysis of Essential Oil, Forage Quality and Digestibility (the first batch)

The first samples were milled to 2 mm pieces and then subjected to SD and EFO methods for 3 hours. At EFO method, the temperature treatments (25, 60, 75 and 90 °C) were tested. Also, the volatile oils were collected, analyzed to GC/MS, and then compared (SD with EFO method). The essential oil yield was obtained according to the following equation:

Where m_{oil} is weight of essential oil in grams and m_s is the weight of the plant in grams.

Then, forage quality and digestibility of plant particles after extracting were analyzed:

Crude protein (CP) was also measured by micro-Kjeldahl apparatus and the percentage of nitrogen was calculated according to the volume of acid consumed in the titration and based on the following equation, [18]:

N (%) ± (Consumed acid volume × acid normality × 1.4) / Sample weight

The following equation was also used to calculate the crude protein content:

Crude protein content (%) ± 6.25 (protein coefficient) × N (%)

The acid detergent fibers (ADF) percentage of the samples was calculated using the following formula [19]: oil and preserving the forage quality and digestibility, an optimal temperature was suggested.

ADF Weight = (weight of the container with sediment after burning) - (weight of the container with sediment before burning)

ADF (%) ± (ADF weight / initial sample weight) × 100

The determination of neutral detergent fibers (NDF) was similar to that of ADF, but the difference was that, instead of using an acidic detergent solution, a neutral detergent solution (NDS) was used [19].

Metabolizable energy (ME) was also calculated using the proposed formula by the Australian Agricultural Standards Committee (1990). The digestible energy (DE) [20] was calculated, as well:

DE (%) ± 0.628+ 0.984 (DDM)

ME (MJ/kg) ± (0.17×DMD%)- 2

Also, 200 mg of the dried plant samples was weighed and its digestibility was measured. In order to correct the gas produced with the origin of the ruminal liquid, 3 replications with no feed sample (Blank) and only with 20 mL of the mixture of ruminal liquid and buffer, were applied? and then placed in the incubator. At different times of 2, 4, 6, 8, 12, 24, 48, 72, and 96 hours after placing the glasses in the shaker-incubator, the amount of gas produced using the Fedorak method (liquid displacement) was recorded. The volume of gas produced based on the weight of the food sample at each time was corrected using the following equation:

$V \pm (V_t\text{-}V_b) \times 100/W$

where V is the corrected volume of gas (mL per gram of dry matter), Vt is the volume of gas produced in glass containing samples of food (mL), Vb is the volume of gas produced in glass without food (blank; mL), and W is the weight of feed sample (mg dry matter).

Measurement of Forage Quality Parameters and Digestibility (the second batch)

For the second sample, only forage quality and digestibility parameters (before extracting) were measured, which were then compared with the first samples (after extracting).

Essential Oil and Forage Quality Optimizer (EFO) Design of the Apparatus

This apparatus has been approved by the Patent Office of Iran with the number 139650740003010883. The description of the apparatus map was designed by AutoCAD software that is as follows (Fig. 2):

The electric circuit box was created to adjust the temperature of the elements according to the order given by the temperature control box, thermal sensor was designed to indicate the temperature of the plant chamber (or plant charge) and heat transfer to the temperature control box, chromium-nickel electric elements was used to create and transfer heat to electrical circuit boxes and the temperature control box was set at the desired temperature. When it displays the desired temperature, the command to cut off the flow would be send to the box of electrical circuits. Also, after decreasing temperature, command to the circuit board for the connection of the flow. The temperature display screen was determined and represented the temperature of the elements. As well as, glass fiber was a fireproof insulation placed around the elements to prevent damage to the plant's chamber through high temperatures, electric element (cross section) for warming up the plant charge and the cotton linen that was placed as a layer on the fiberglass.

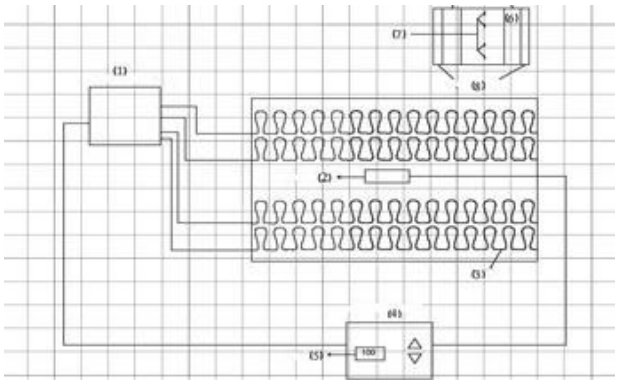

Fig. 2 A two-dimensional view of the longitudinal and cross sections of the apparatus designed with AutoCAD software.

Setting up Apparatus and Run it

Essential oil and forage quality optimizer (EFO) were embedded on a steam distillation (SD) apparatus (Fig. 3). As shown in this figure, the apparatus (EFO) covering the whole the plant particles charge are located. By starting the boiling water in flask containing water and passing steam between plant materials, the optimizer could be connected to the electricity. The heat sensor was installed to transfer and adjust the heat from the plant charge to the control box between the elements. To regulate the heating elements, the box of electrical circuits was connected to the temperature control box. The temperature of the control box was adjusted on the desired temperature (e.g. 60, 75 or 90 °C). When the temperature of heat sensor reached above the desired temperature, the control box sent the power cut-off command to the circuit board and cut the electricity of the elements. By decreasing the temperature lower than the studied temperature, the restart command was given by the control box to the electric circuit board and the electricity was then restored. Therefore, at first, the apparatus was adjusted on the desired temperatures (e.g. 60, 75 or 90 °C). Afterward, the essential oil was extracted, and forage quality parameters and digestibility of plant materials were measured. Eventually, according to the yield of essential

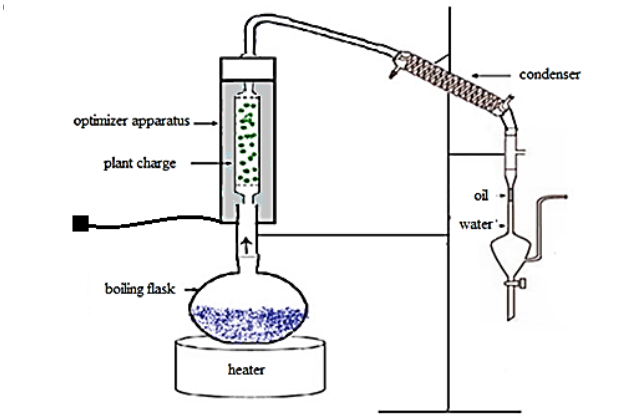

Fig. 3 The optimizer embedded on a steam distillation apparatus

GC/MS Analysis

The oils were analyzed using an Agilent 6890 gas chromatograph fitted with an Agilent 5973N mass spectrometer on a BPX5 column (30 m × 0.25 mm capillary column, 0.25 µm film thickness) under the following conditions: carrier gas, helium; flow rate, 0.5 mL/min; column temperature programmed from 50 °C to 300 °C at 3 °C/min; injection port temperature, 220 °C; ionization voltage, 70 eV, oil sample size, 1 µl, the split ratio, 1:35, mass range, and m/z 40-500 a.m.u. In addition, retention indices were determined using *n*-alkane mixture under the same conditions as described earlier. Afterward, the separated components were identified by matching with the NIST mass-spectral library data and by comparing the Kovat's indices with those of authentic components and with the published data [21,22].

Statistical Analysis

Collected data were normalized using the Kolmogorov-Smironov test. Then, a combination of one-way ANOVA and because the Tukey test shows the differences better, was used to compare the quality and essential oil of forage. Essential oils of plantsamples in SD and at three temperature treatments (60, 75, and 90 °C) of EFO were evaluated. These methods were performed using SPSS 19 software and charts drawn using Excel 2010.

Results

Essential Oil Chemical Constituents Obtained by SD and EFO

The results showed that the extraction procedure significantly affected the essential oil percentage in *P. ferulaceae* According to the resulted presented in Figure 3, the EFO procedure increased the quantity of EO terpenoids, and saved forage quality and digestibility in dry plant aerial parts. There was a significant difference between treatments of steam distillation at 60, 75, and 90 °C in combined method. There was no significant difference between the temperatures of 75 and 90 °C. Also, the lowest oil percent was obtained for water distillation by 0.16% and the highest amount was for EFO at 90 °C in combined method (1.47%). Moreover, the EFO at 60, 75, and 90 °C of EFO resulted to 3-, 7.8-, and 9-times higher essential oil percent compared to the SD (Fig. 4).

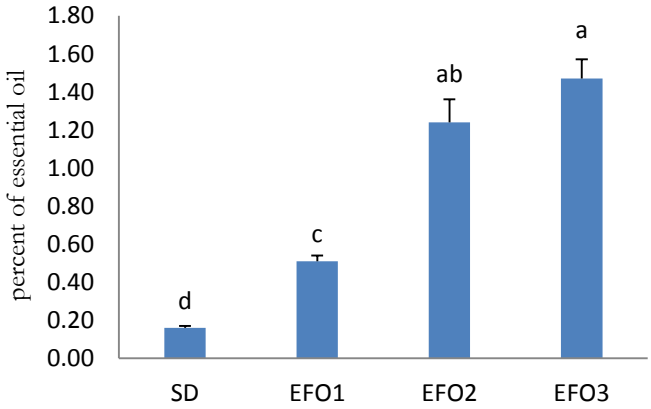

Fig. 4 Percent of essential oil of *P. ferulaceae* (L.) Lindl in two different extraction methods (SD and EFO)
Different letters indicate the significant difference between treatments ($p < 0.01$). EFO1: 60, EFO2: 75 and EFO3: 90 °C.

The essential oil compositions (mean ± standard error) of P. *ferulacea* compared in four extraction treatments (SD and EFO at 60, 75, and 90 °C; Table 1). According to the results, for most compounds, the EFO at 75 °C, had a significant difference with the other treatments and had the highest value of different compounds. among the studied compounds, the most important one include limonene, δ-3-Carene, Dihydro linalool, E-Caryophyllene, α-Humulene, E-β-Farnesene, α-selinene, Spathulenol, globulol, β-eudesmol, and α-Bisabolol. E-Caryophyllene had the highest percentage among the other detected compounds and the EFO at 90 °C had the highest value which had significant difference with other extraction methods. In most of detected compounds, EFO at 75 °C had the highest amount of the compound which had significant difference with other treatments. As shown in Table 1, EFO at 90 °C was not able to detect some of compounds including sabinene and linalool while all of the compounds were detected using EFO at 75 °C. Totally, results showed that EFO at 75 °C was better treatment for essential oil extraction compared to the other treatments. EFO at 75°C resulted to the highest amount of myrcene, limonene and δ-3-Carene compared to the other treatments and this treatment extracted all of detected compounds (Table 1).

Table 1 Oils chemical compositions of *P. ferulaceae* (L.) Lindl (Mean ± Std. Error) using different extraction methods (SD and EFO).

No	Compound	RI	Essential oil constituents (%)			
			SD	EFO1	EFO2	EFO3
1	Sabinene	974	0.58±0.05 a	0.35±0.202 c	0.42±0.04 b	-
2	Myrcene	999	0.51±0.11 b	1.35±0.574 a	0.43±0.04 c	0.24±0.139 d
3	Limonene	1028	0.47±0.09 d	1.11±0.093 a	0.79±0.01 b	0.60±0.173 c
4	δ-3-Carene	1030	1.19±0.07 c	1.32±0.029 b	3.01±0.01 a	0.47±0.038 d
5	γ-terpinene	1075	0.52±0.02 c	0.79±0.006 b	1.16±0.36 a	0.46±0.038 c
6	Terpinolene	1081	0.62±0.14 c	1.66±0.390 a	0.99±0.39 b	0.29±0.032 d
7	Dihydro linalool	1092	1.17±0.06 b	1.12±0.02 b	1.92±0.34 a	0.57±0.153 c
8	Linalool	1097	0.64±0.04 ab	0.37±0.014 c	0.59±0.15 b	-
9	α-longipinene	1353	-	0.51±0.043 a	0.32±0.18 b	0.34±0.017 b
10	Nevyl acetate	1364	0.68±0.01 a	0.62±0.012 b	0.72±0.2 a	0.49±0.115 c
11	Italicene	1405	0.66±0.02 a	0.47±0.026 b	0.68±0.07 a	0.54±0.069 b
12	E-Caryophyllene	1420	48.9±0.39 bc	54.50±2.64 b	56.3±0.56 ab	60.41±2.832 a
13	α-Humulene	1450	4.05±0.03 d	4.71±0.139 b	4.64±0.03 c	4.76±0.095 a
14	E-β-Farnesene	1458	3.15±0.2 ab	2.35±0.248 c	3.23±0.01 a	0.86±0.020 d
15	7-epi-1,2-dihydro sesquicineol	1471	1.00±0.03 c	0.82±0.003 d	1.53±0.04 a	1.13±0.101 b
16	γ-Muurolene	1480	1.75±0.08 a	1.62±0.026 b	1.53±0.07 bc	1.15±0.173 d
17	Epi- cubenol	1493	0.75±0.01 bc	0.78±0.012 bc	0.89±0.08 c	0.70±0.026 ab
18	α-selinene	1497	0.57±0.01 b	0.65±0.410 a	0.59±0.07 b	0.44±0.089 c
19	Spathulenol	1577	9.75±0.36 b	4.84±0.205 c	11.4±0.48 a	5.53±0.150 c
20	Caryophyllen oxide	1582	0.67±0.03 a	0.33±0.006 b	0.66±0.04 a	0.30±0.003 b
21	globulol	1586	2.12±0.17 a	0.59±0.05 c	1.45±0.01 b	0.35±0.017 c
22	β-eudesmol	1650	2.48±0.14 b	1.46±0.046 c	2.95±0.41 a	1.23±0.075 d
23	α-bisabolol	1684	3.33±0.14 b	3.57±0.11 a	3.55±0.4 a	2.18±0.48 c
24	dihydrocarveol acetate	1705	-	0.24±0.326 b	0.36±0.21 b	5.99±1.02 a
25	γ-himachalene	1725	-	1.25±0.153 b	1.31±0.06 b	2.17±0.040 a

Different letter indicate the significant difference between treatments ($P < 0.05$). EFO1: 60, EFO2: 75 and EFO3: 90 °C. RI:Retention indices, determined on BPX5 capillary colum

Forage Quality and Digestibility Analysis

Table 2 shows the forage quality indices f *P. ferulacea* (Mean ± Std. Error) before and after extracting essential oil oils by two different extraction methods (SD and EFO). All of calculated indices had the highest values in samples before extraction which had significant difference with extraction treatments. The highest DMD, CP, ADF, NDF and ME content obtained by 65.29, 19.23, 31.05, 37.24 percent and 9.11 Mj/kg, respectively, at samples before extraction of essential oils. While, DE content was the lowest before extraction of EO by 64.30 percent. For DMD, the highest value obtained at SD treatment which had no significant difference with EFO at 25 °C (64.46 and 63.42 percent, respectively).

Table 2 The forage quality indices f *P. ferulacea* (Mean ± Std. Error) before and after extracting essential oil oils by two different extraction methods (SD and EFO).

Parameter (%)	Sample of before extraction	Samples of after extraction			
		SD	EFO1	EFO2	EFO3
DMD	65.29±0.033 a	64.46±0.15 b	63.42±0.11 b	61.58±0.12 c	58.67±0.26 d
CP	19.23±0.009 a	17.54±0.07 b	16.79±0.08 c	16.33±0.07 c	13.44±0.07 d
ADF	31.05±0.02 a	28.18±0.02 b	25.23±0.05 c	23.29±0.07 d	21.57±0.15 e
NDF	37.24±0.07 a	36.26±0.1 b	34.56±0.05 c	32.77±0.18 d	30.98±0.07 e
ME (Mj/kg)	9.11±0.006 a	8.96±0.03 a	8.78±0.02 c	8.47±0.02 b	7.97±0.04 a
DE	64.30±0.01 e	66.5±0.02 d	68.77±0.04 c	70.3±0.05 b	71.57±0.12 a

(DMD: digestible dry matter, CP: Crude protein, ME: metabolizable energy, ADF: acid detergent fibers, NDF: neutral detergent fibers, DE: digestible energy). Different letters in each row indicate the significant difference between treatments ($P < 0.05$). EFO1: 60, EFO2: 75 and EFO3: 90 °C.

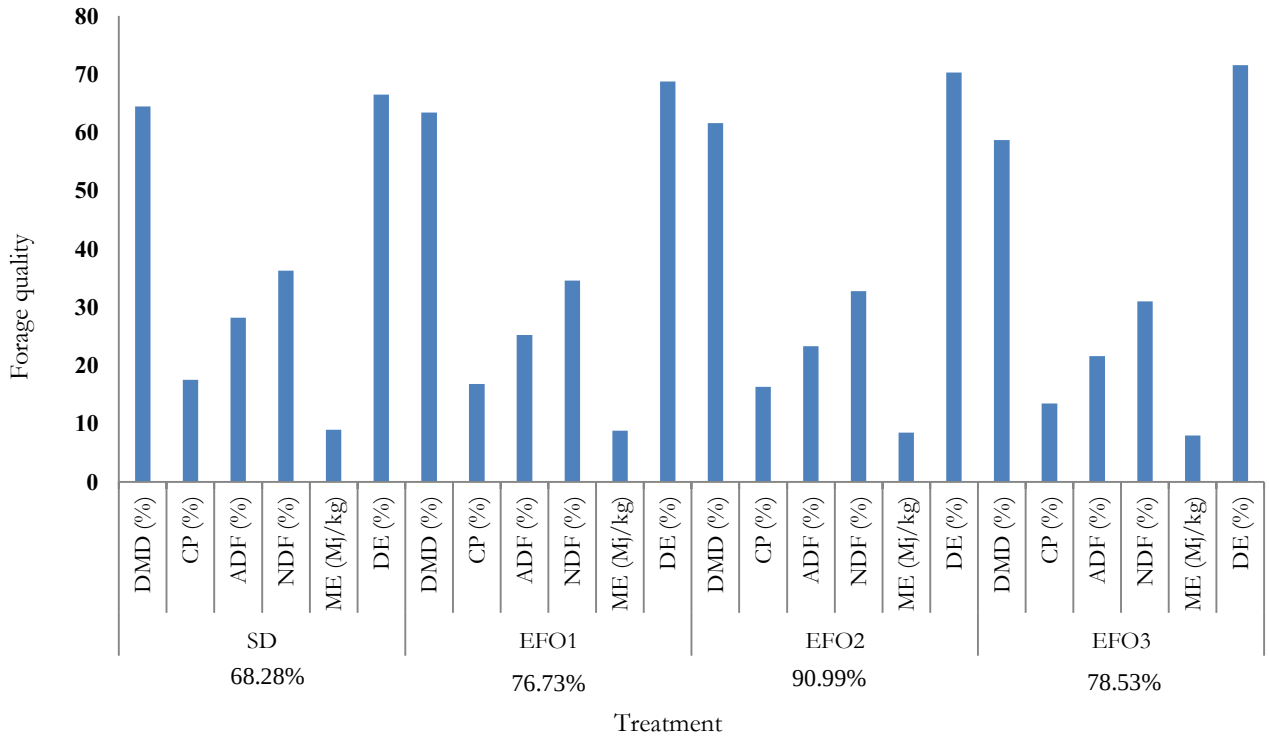

Fig. 5 The forage quality indices f *P. ferulacea* (Mean ± Std. Error) after extraction of plant essential oils by two different extraction methods (SD and EFO). (DMD: digestible dry matter, CP: Crude protein, ME: metabolizable energy, ADF: acid detergent fibers, NDF: neutral detergent fibers, DE: digestible energy). Different letters in each row indicate the significant difference between treatments ($P < 0.05$). EFO1: 60, EFO2: 75 and EFO3: 90 °C.

Among the extraction treatments, EFO at 25 °C had the highest amount pf CP, ADF, NDF and ME by 17.54, 28.18, 36.26 percent and 8.96 Mj/kg, respectively and EFO at 90 °C had the lowest value of these indices. For DE content, increasing the extraction temperature resulted to increase in DE content and the highest value observed in EFO extraction method at 90 °C which had significant difference with other treatments and the lowest amount observed in the EFO at 25 °C by 66.5 percent (Table 2, Fig. 5). Table 3 compares the mean gas production rate at different incubation times before and after extraction of essential oils by two different extraction methods (SD and EFO). Results showed that increasing incubation time increased the gas production rate and 96 hours incubation had the highest gas production rate for extraction methods and even before extraction. There was no significant different between 48 and 72 hours for before extraction, EFO at 25, 50 and 75 °C. among extraction methods, the highest gas production recorded in SD treatment at 96 hours incubation by 72.18 mL/200 mg DM followed by EFO at 90 °C by 72.13 mL/200 mg DM. also, results showed that increasing the extraction temperature resulted to increase in gas production rate and the highest values obtained in EFO at 90 °C treatments (Table 3, Fig. 6).

Table 3 Comparison of the average amount of gas production [mL/g DM]at different incubation times before and after extraction of essential oils by two different extraction methods (SD and EFO).

Treatments		Incubation time (hours)								
		2	4	6	8	12	24	48	72	96
Sample of before extraction		11.84 h	23.01 g	34.5 f	41.34 e	52.34 d	60.51 c	66.01 b	67.51 b	70.51 a
Samples of after extraction	SD	10.67 i	15.51 h	27.17 g	37.34 f	48.34 e	59.67 d	66.84 c	69.01 b	72.18 a
	EFO1	12.17 h	23.84 g	34.67 f	41.84 e	51.84 d	58.34 c	62.51b c	63.84 b	66.51 a
	EFO2	13.34 h	25.01 g	37.00 f	43.67 e	54.84 d	62.51 c	67.68 b	68.84 b	71.18 a
	EFO3	13.35 f	25.10 g	37.80 f	44.90 e	56.20 d	63.10 c	68.01 b	69.30 b	72.13 a

Different letters in each row indicate the significant difference between treatments ($P < 0.05$). EFO1: 60, EFO2: 75 and EFO3: 90°C. Cumulative gas (mL/g Dm)

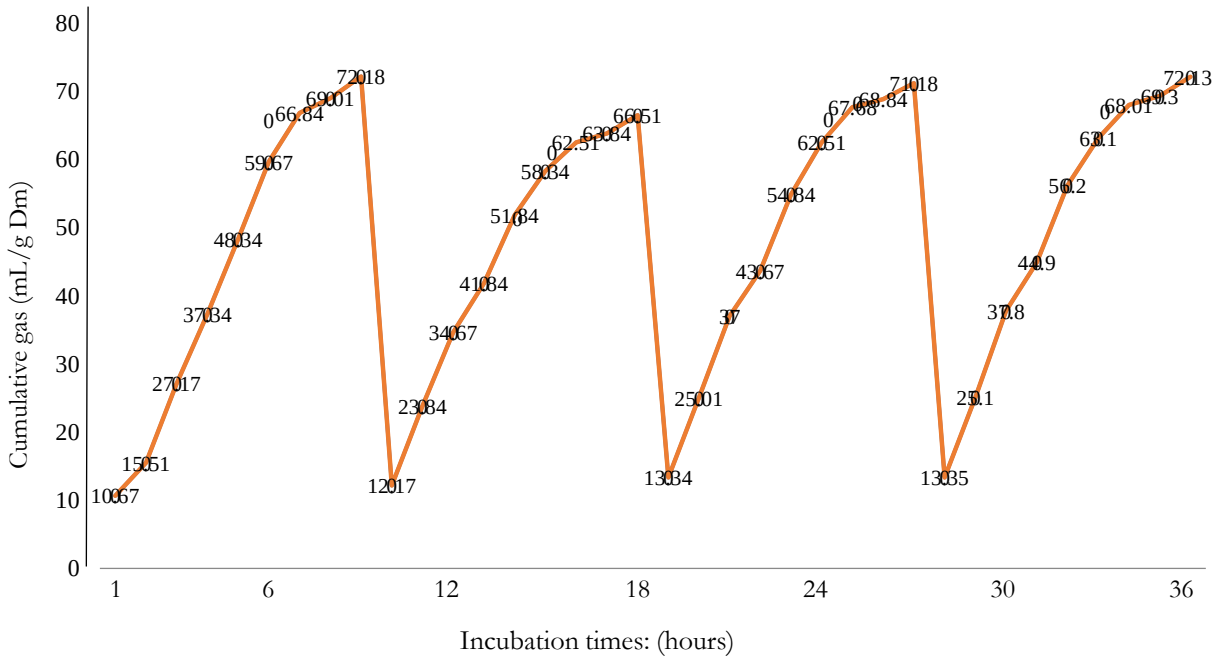

Fig. 6 Average amount of gas production at different incubation after extraction of essential oils by two different extraction methods (SD and EFO). EFO1: 60, EFO2: 75 and EFO3: 90 °C.

Discussion

The 75 and 90 °C temperatures had the most essential oil yields, and these treatments had 8 to 9 times more essential oil contents than SD and EFO1 treatments. EFO2 treatment at 75 °C, in terms of the important components of essential oil, had the most essential oil content compared to the other treatments. Correspondingly, this is in agreement with a study by Zhang *et al*. [23], which found that a higher separation efficiency require a lower energy consumption, which also has certain advantages in the separation of EO with higher proportion of oxygenated components as well as a better antioxidant activity from *Paeonia* × *suffruticosa* Andrews by a novel microwave-assisted steam distillation approach. In the other study, ohmic-assisted hydrodistillation was used to extract the essential oils of *P. ferulacea*. The results of this study showed that not only a selective extraction of some components can achieve via ohmic procedure, but also it is a more economical and environmentally friendly procedure that can be considered as a green technology [24].

In the forage quality measurement method, 75 °C had the most important parameters for improving forage quality (digestible dry matter, crude protein, metabolic energy, digestible energy and relative nutritional value) compared to other treatments. Moreover, it had the least amount of anti-quality parameters (ADF and NDF) compared with the sample of before extraction and SD. Also, this treatment was better than the other treatments in terms of forage value. So that, after 90 °C, it had the highest digestible energy and relative nutritional values. No previous studies have been conducted to maintain forage quality after essential oil extraction.

Due to the fact that the digestibility of feed samples in EFO method is more than the other two treatments (sample before extraction and SD), this method has likely caused more degradation of raw fiber. However, the intensive hydrothermal processes i.e. EFO method can improve protein and digestibility of feed through reducing the anti-quality parameters. [25-27]. Totally, EFO2 treatment significantly maximized the total amount of pure product obtained from the major compounds (11 volatiles) in the essential oil while maintaining forage quality and digestibility, compared to the conventional SD and the other EFO treatments. Therefore, in innovative method, 75 °C was identified as the most appropriate temperature to increase oils yield and maintain the forage quality in *P. ferulacea* medicinal-forage species. A reason for increasing the essential oil content and maintaining the forage quality using the innovative optimizer method could be summarized as follows:

Initially, water steam causes the evaporation or distillation of essential oil compounds through molecular penetration on plant particles as well as the creation of mass transfer operations and the onset of a two film theory [28]. However, by reducing the energy of water vapor due to the use of heat in the mass transfer from the liquid phase (essential oil compounds) to the gas phase

(water vapor), along with the exchange of heat with the environment of the plant chamber, the reduction of enthalpy occurred in the system, and in the layers of the plant mass, essential oil slightly evaporated. Thus, during the distillation process, a significant amount of essential oil was not extractable, and the creation of a secondary heat was required for distillation of the organic matter in the plant particles [29]. Therefore, by increasing the temperature within the plant chamber through the EFO optimizer and increasing the mass transfer (transfer of material from plant particles to water vapor), based on the theory of two films, the amount of extracted essential oil and its purity can be increased and the quality of forage can also be maintained. In the stem distillation method, the material is placed on a perforated plate above the steam inlet. It is easy to control how much steam is generated in the steam generating mechanisms. Furthermore, since the steam generator is outside of the distillation unit, the ambient temperature at which the material to be distilled is located is kept below 100 °C and the occurrence of impairments due to the heat effect can be prevented or reduced [30]. The biggest problem of the steam distillation is the vapor pressure and the degradation which can occur when the flow rate is high [31]. The Essential oil and forage quality optimizer (EFO) method had increased the amount of essential oil and its major components, while preserved the forage quality in medicinal-forage plants. These compounds are extensively used in the pharmaceutical industry. On the other hand, by obtaining forage quality higher than traditionally harvested forage, a nutritious feed for livestock can be introduced to the animal feed industry. Eventually, development of such studies by optimal and multi-purpose usages of these plants, leads to the maximum value of phytochemical and feed products as well as increasing their economic value and commercial profit.

Conclusion

As a result, application of the innovative EFO method could be considered as a good strategy for species that have both medicinal properties and high forage quality. So that the medicinal composition could be utilized in various applications, and the nutritional value of forage could also be preserved. It should be noted that, no researcher have used such a method in a multifunctional way so far (both increasing the essential oil yield and maintaining the quality and digestibility of forage). Therefore, this method can be considered as an effective step for the economical utilization of medicinal- forage species.

Declaration of Competing Interest

The authors confirm that there are not conflicts of interest in this research.

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